

WHAT IS CLAIMED IS:

1. A projection optical system for forming an image of a pattern of a first object on a second object, comprising an optical material having a refractive index of not more than 1.6, which is
5 disposed in an optical path between the first object and the second object,

said projection optical system being substantially telecentric both on the first object side and on the second object side, and
10

said projection optical system satisfying the condition below:

$$(\lambda \times L) / (NA \times Y_0^2) < 1.5 \times 10^{-3},$$

where λ is a wavelength of light used by the projection optical system, L a distance between the
15 first object and the second object, NA a numerical aperture on the second object side, and Y_0 a maximum image height on the second object.

2. The projection optical system according to Claim 1, which satisfies the condition below:
20

$$E/L > 1.2,$$

where E is a distance between an exit pupil of the projection optical system and the second object and L the distance between the first object and the second
25 object.

3. The projection optical system according to

Claim 2, wherein all optical components constituting the projection optical system are made of an optical material of a single kind.

4. The projection optical system according to
5 Claim 3, wherein at least one optical surface is formed
in an aspherical shape.

5. The projection optical system according to Claim 4, which comprises, in order from the first object side, a first lens unit having a positive
10 refracting power, a second lens unit having a negative refracting power, and a third lens unit having a positive refracting power.

6. The projection optical system according to Claim 5, wherein, where H_0 represents a maximum object
15 height on the first object,

80% or more of the total number of optical surfaces constituting the first lens unit have a clear aperture radius larger than 1.1 times the maximum object height H_0 ,

20 80% or more of the total number of optical surfaces constituting the second lens unit have a clear aperture radius smaller than 1.1 times the maximum object height H_0 , and

70% or more of the total number of optical
25 surfaces constituting the third lens unit have a clear aperture radius larger than 1.1 times the maximum

object height H_0 .

7. The projection optical system according to Claim 6, wherein the first lens unit is disposed nearest to the first object among the lens units
5 belonging to the projection optical system, and

wherein the third lens unit is disposed nearest to the second object among the lens units belonging to the projection optical system.

8. An exposure apparatus comprising:
10 an illumination system for illuminating the first object; and

the projection optical system as set forth in Claim 7, for forming an image of a pattern formed on the first object, on the second object.

15 9. The exposure apparatus according to Claim 8, said exposure apparatus implementing exposure in a state in which the first object and the second object are stationary relative to each other with respect to a transverse direction to the optical axis of the
20 projection optical system.

10. A device production method comprising:
an illumination step of illuminating the first object;

an exposure step of implementing exposure of a
25 pattern of the first object illuminated by the illumination step, to the second object by way of the

projection optical system as set forth in Claim 7; and
a development step of developing the second
object exposed by the exposure step.

11. The device production method according to
5 Claim 10, wherein said exposure step is to implement
the exposure in a state in which the first object and
the second object are stationary relative to each other
with respect to a transverse direction to the optical
axis of the projection optical system.

10 12. The projection optical system according to
Claim 1, wherein all optical components constituting
the projection optical system are made of an optical
material of a single kind.

13. The projection optical system according to
15 Claim 1, wherein at least one optical surface is formed
in an aspherical shape.

14. The projection optical system according to
Claim 1, which comprises, in order from the first
object side, a first lens unit having a positive
20 refracting power, a second lens unit having a negative
refracting power, and a third lens unit having a
positive refracting power.

15. The projection optical system according to
Claim 14, wherein, where H_0 represents a maximum object
25 height on the first object,

80% or more of the total number of optical

surfaces constituting the first lens unit have a clear aperture radius larger than 1.1 times the maximum object height H_0 ,

5 80% or more of the total number of optical surfaces constituting the second lens unit have a clear aperture radius smaller than 1.1 times the maximum object height H_0 , and

10 70% or more of the total number of optical surfaces constituting the third lens unit have a clear aperture radius larger than 1.1 times the maximum object height H_0 .

15 16. The projection optical system according to Claim 15, wherein the first lens unit is disposed nearest to the first object among the lens units belonging to the projection optical system, and

wherein the third lens unit is disposed nearest to the second object among the lens units belonging to the projection optical system.

20 17. The projection optical system according to Claim 1, wherein a reduced image of the first object is formed on the second object.

18. An exposure apparatus comprising:

an illumination system for illuminating the first object; and

25 the projection optical system as set forth in Claim 1, for forming an image of a pattern formed on

the first object, on the second object.

19. The exposure apparatus according to Claim 18, said exposure apparatus implementing exposure in a state in which the first object and the second object are stationary relative to each other with respect to a
5 transverse direction to the optical axis of the projection optical system.

20. A device production method comprising:
an illumination step of illuminating the first
10 object;

an exposure step of implementing exposure of a pattern of the first object illuminated by the illumination step, to the second object by way of the projection optical system as set forth in Claim 1; and
15 a development step of developing the second object exposed by the exposure step.

21. The device production method according to Claim 20, wherein said exposure step is to implement the exposure in a state in which the first object and the second object are stationary relative to each other
20 with respect to a transverse direction to the optical axis of the projection optical system.

22. A projection optical system for forming an image of a pattern of a first object on a second
25 object, comprising an optical material disposed in an optical path between the first object and the second

object; and at least one optical surface formed in an aspherical shape,

said projection optical system being substantially telecentric both on the first object side and on the second object side,

said projection optical system satisfying the conditions below:

$$(\lambda \times L) / (NA \times Y_0^2) < 1.0 \times 10^{-3}, \text{ and}$$

$$\lambda < 200 \text{ nm},$$

where λ is a wavelength of light used by the projection optical system, L a distance between the first object and the second object, NA a numerical aperture on the second object side, and Y_0 a maximum image height on the second object.

23. The projection optical system according to Claim 22, wherein a reduced image of the first object is formed on the second object.

24. An exposure apparatus comprising:

an illumination system for illuminating the first object; and

the projection optical system as set forth in Claim 22, for forming an image of a pattern formed on the first object, on the second object.

25. The exposure apparatus according to Claim 24, said exposure apparatus implementing exposure in a state in which the first object and the second object

are stationary relative to each other with respect to a transverse direction to the optical axis of the projection optical system.

26. A device production method comprising:

5 an illumination step of illuminating the first
object;

 an exposure step of implementing exposure of a
pattern of the first object illuminated by the
illumination step, to the second object by way of the
10 projection optical system as set forth in Claim 22; and
 a development step of developing the second
object exposed by the exposure step.

27. The device production method according to
Claim 26, wherein said exposure step is to implement
15 the exposure in a state in which the first object and
the second object are stationary relative to each other
with respect to a transverse direction to the optical
axis of the projection optical system.

28. A projection optical system for forming an
20 image of a pattern of a first object on a second
object, comprising the following lens units in order
from the first object side:

 a first lens unit having a positive refracting
power;
25 a second lens unit having a negative refracting
power; and

a third lens unit having a positive refracting power,

said projection optical system satisfying the condition below:

5 $0.014 < Y_0/L < 0.030,$

where Y_0 is a maximum image height on the second object and L a distance between the first object and the second object.

29. The projection optical system according to
10 Claim 28, wherein, where H_0 represents a maximum object height on the first object,

80% or more of the total number of optical surfaces constituting the first lens unit have a clear aperture radius larger than 1.1 times the maximum
15 object height H_0 ,

80% or more of the total number of optical surfaces constituting the second lens unit have a clear aperture radius smaller than 1.1 times the maximum object height H_0 , and

20 70% or more of the total number of optical surfaces constituting the third lens unit have a clear aperture radius larger than 1.1 times the maximum object height H_0 .

30. The projection optical system according to
25 Claim 29, wherein the first lens unit is disposed nearest to the first object among the lens units

belonging to the projection optical system, and

wherein the third lens unit is disposed nearest to the second object among the lens units belonging to the projection optical system.

5 31. The projection optical system according to Claim 30, wherein a reduced image of the first object is formed on the second object.

 32. An exposure apparatus comprising:
an illumination system for illuminating the first
10 object; and

the projection optical system as set forth in Claim 31, for forming an image of a pattern formed on the first object, on the second object.

 33. The exposure apparatus according to Claim
15 32, said exposure apparatus implementing exposure in a state in which the first object and the second object are stationary relative to each other with respect to a transverse direction to the optical axis of the projection optical system.

20 34. A device production method comprising:
an illumination step of illuminating the first object;

an exposure step of implementing exposure of a pattern of the first object illuminated by the
25 illumination step, to the second object by way of the projection optical system as set forth in Claim 31; and

a development step of developing the second object exposed by the exposure step.

35. The device production method according to Claim 34, wherein said exposure step is to implement the exposure in a state in which the first object and the second object are stationary relative to each other with respect to a transverse direction to the optical axis of the projection optical system.

36. The projection optical system according to Claim 28, wherein the first lens unit is disposed nearest to the first object among the lens units belonging to the projection optical system, and

wherein the third lens unit is disposed nearest to the second object among the lens units belonging to the projection optical system.

37. An exposure apparatus comprising:
an illumination system for illuminating the first object; and

the projection optical system as set forth in Claim 28, for forming an image of a pattern formed on the first object, on the second object.

38. The exposure apparatus according to Claim 37, said exposure apparatus implementing exposure in a state in which the first object and the second object are stationary relative to each other with respect to a transverse direction to the optical axis of the

projection optical system.

39. A device production method comprising:

an illumination step of illuminating the first object;

5 an exposure step of implementing exposure of a pattern of the first object illuminated by the illumination step, to the second object by way of the projection optical system as set forth in Claim 28; and
10 a development step of developing the second object exposed by the exposure step.

40. The device production method according to Claim 39, wherein said exposure step is to implement the exposure in a state in which the first object and the second object are stationary relative to each other
15 with respect to a transverse direction to the optical axis of the projection optical system.

41. An exposure method of implementing projection exposure of a pattern on a mask onto a photosensitive substrate, comprising:

20 an illumination step of illuminating the mask with use of an illumination system; and

 a projection step of forming a reduced image of the pattern of the mask on the photosensitive substrate with use of a projection optical system,

25 wherein the projection optical system is made of an optical material having a refractive index of not

more than 1.6 and is substantially telecentric both on the mask side and on the photosensitive substrate side, and

wherein the projection optical system satisfies the condition below:

$$(\lambda \times L) / (NA \times Y_0^2) < 1.5 \times 10^{-3},$$

where λ is a wavelength of light from the illumination system, L a distance between the mask and the image of the mask, NA a numerical aperture on the photosensitive substrate side, and Y_0 a maximum image height on the photosensitive substrate.

42. The exposure method according to Claim 41, wherein the projection step is to implement exposure in a state in which the mask and the photosensitive substrate are stationary relative to each other with respect to a transverse direction to the optical axis of the projection optical system.

43. An exposure method of implementing projection exposure of a pattern on a mask onto a photosensitive substrate, comprising:

an illumination step of illuminating the mask with use of an illumination system; and

a projection step of forming a reduced image of the pattern of the mask on the photosensitive substrate with use of a projection optical system,

wherein the projection optical system is made of

an optical material having a refractive index of not more than 1.6, is substantially telecentric both on the mask side and on the photosensitive substrate side, and has at least one optical surface formed in an aspherical shape, and

wherein the projection optical system satisfies the conditions below:

$$(\lambda \times L) / (NA \times Y_0^2) < 1.0 \times 10^{-3}, \text{ and}$$

$$\lambda < 200 \text{ nm},$$

where λ is a wavelength of light from the illumination system, L a distance between the mask and the image of the mask, NA a numerical aperture on the photosensitive substrate side, and Y_0 a maximum image height on the photosensitive substrate.

44. The exposure method according to Claim 43, wherein the projection step is to implement exposure in a state in which the mask and the photosensitive substrate are stationary relative to each other with respect to a transverse direction to the optical axis of the projection optical system.

45. An exposure method of implementing projection exposure of a pattern on a mask onto a photosensitive substrate, comprising:

a step of positioning the mask on a first surface;

a step of positioning the photosensitive

substrate on a second surface;

an illumination step of illuminating the mask;

and

a projection step of forming a reduced image of
 5 the pattern of the mask on the photosensitive substrate
 with use of a projection optical system;

wherein the projection optical system comprises a
 first lens unit disposed in an optical path between the
 first surface and the second surface and having a
 10 positive refracting power, a second lens unit disposed
 in an optical path between the first lens unit and the
 second surface and having a negative refracting power,
 and a third lens unit disposed in an optical path
 between the second lens unit and the second surface and
 15 having a positive refracting power, and

wherein the projection optical system satisfies
 the condition below:

$$0.014 < Y_0/L < 0.030,$$

where Y_0 is a maximum image height on the
 20 photosensitive substrate and L a distance between the
 mask and the photosensitive substrate.

46. The exposure method according to Claim 45,
 wherein the projection step is to implement exposure in
 a state in which the mask and the photosensitive
 25 substrate are stationary relative to each other with
 respect to a transverse direction to the optical axis

of the projection optical system.
